New insights into the structure and evolution of the Isle of Wight Monocline

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Abstract

High quality seismic reflection data acquired during hydrocarbon exploration activities provide evidence for the subsurface structure and evolution of one of England's most well known structures at outcrop: the Isle of Wight Monocline. It is generally seen as a major northerly verging monoclinal structure linked to the Purbeck Monocline to the west. The Isle of Wight Monocline is the result of the interplay between two east-west trending, southerly dipping and overlapping down-to-the-south major syndepositional normal faults that were active during Triassic and Jurassic times: the Needles and Sandown faults. The area between the two faults tips forms an easterly-dipping relay ramp, down which sequences of all ages thicken. Both of these major normal faults were inverted during Cenozoic (Miocene: Alpine) compressional events, folding the overlying post-rift sequences of early Cretaceous to early Cenozoic (Palaeogene) age. Interpretation of the seismic reflection data suggest that a previously unknown high-angle, down-to-the-north reverse fault cuts the northern limb of both anticlines forming the composite monocline and was likely to come to crop in the steeply-dipping Chalk and/or the drift-covered Cenozoic sequences. Its identification marked a period of discussions and testing of the model by detailed field mapping. The existence and location of such a fault was proved through an iterative process with the result that a reverse fault zone is now mapped along the northern limb of the northern Sandown Anticline section of the Monocline. The main reverse faults on the Brighstone and Sandown anticlines result in circa 550 m of displacement at top Chalk level. It is thought that a series of smaller footwall short-cut faults affect the Cenozoic strata to the north of the main reverse fault, producing up-faulted sections of flatter-lying Cenozoic strata. Reverse displacements and the severity of folding on the inverted faults decreases on each fault segment in a complementary fashion in the area of the relay ramp as one fault takes up the movement at the expense of the other. The swing in strike of the Chalk in the area of shallowly dipping strata between Calbourne and Garstons is a result of deformation of the post-rift sequences across the relay ramp established between the overlapping fault tips of the Needles and Sandown faults and the interaction of the folds developed at the tips of the reverse faults.

Introduction

The Isle of Wight is a classic area of southern Britain's geology. Along with other areas of the Wessex and Weald basins, its structures have attracted interest from the very early days of research and geological mapping (e.g. Lamplugh, 1920; Arkell, 1933, 1947; Falcon and Kent, 1950; House, 1961; Ridd, 1973; Whittaker, 1985; Lake and Karner, 1987; Chadwick, 1986, 1993; Underhill and Patterson, 1998). The dominant structural features of the Isle of Wight are two en échelon, slightly curvilinear folds referred to as the Sandown and Brighstone (formerly Brixton) anticlines (Figs 1 and 2). Together, they are generally referred to as the Isle of Wight Monocline, which extends east-west across the entire length of the island from the Needles in the west, to Culver Cliff in the east. The folds overlap and replace each other just west of the River Medina.

This paper describes a detailed study, based upon interpretations of high-quality seismic reflection data, of the structure and evolution of the Isle of Wight Monocline, undertaken on as support to the BGS 1:50k sheet resurvey. The interpretation of seismic reflection data has had a significant impact on the surface mapping and the paper does not seek to illustrate the well established extensional history of the underlying faults. Instead, it aims to summarise and outline the current thinking on the structural evolution of this classic area of southern England. In particular the inversion of the extensional faults and the development of a major reverse fault and small-scale structures developed along the steepened northern limb of the Isle of Wight Monocline. Combined, they help in understanding the Cenozoic deformation and structural history that produced the Isle of Wight Monocline seen at crop today.

Structural framework

The Sandown and Brighstone anticlines (Fig. 1), are two of a number of narrow, east-west trending fold belts of mid Cretaceous to mid Cenozoic strata at crop onshore within the Wessex Basin many of which are distinctly asymmetric and often comprising monoclinal structures with steeper northern limbs (refer Whittaker, 1985; Penn et al., 1987; Chadwick, 1986, 1993). The Isle of Wight Monocline is the eastern element of a major line of inversion extending from Lyme Bay in the west, eastwards through Purbeck onto the Isle of Wight and beyond into the English Channel (Chadwick, 1986, 1993; Chadwick and Evans, 2005). This major structural zone is known as the Portland-Wight Fault Zone, which is divided into three segments of differing but distinctive character. The western part comprises the Abbotsbury-Ridgeway Fault associated with the Weymouth Anticline, which passes eastwards into the Sutton Poyntz, Poxwell and Chaldon Herring anticlines (Fig. 1). These structures in turn pass eastwards into the Purbeck-Wight Disturbance, with which the Ringstead, Kimmeridge, Purbeck, Brighstones and Sandown anticlines are associated.

It is only with the advent of seismic reflection data, acquired during hydrocarbon exploration in the south of England that the nature of the structures lying beneath the surface folds has been imaged and the causal mechanism for the folding identified. These seismic lines reveal that the east-west trending folds lie above major basin-controlling faults which initially formed during extensional basin formation but were subsequently inverted (Colter and Havard, 1981; Stoneley, 1982, Whittaker, 1985; Chadwick, 1986, 1993; Lake and Karner, 1987; Underhill and Patterson, 1998). A system of asymmetrical graben or half grabens formed during episodic pulses of extension during Permian to Cretaceous times. The basins were bounded by generally east-west trending zones of large en échelon normal faults with dominantly southerly dip and downthrow directions. The present day basin architecture reflects the interplay between the extensional faults and subsequent overprint of Cenozoic basin shortening (inversion). During inversion, the major normal faults suffered reversal of movement, which produced narrow curvilinear zones of often intense folding in the post-rift succession, and locally, reverse faulting with associated small scale deformation structures such as back thrusts. At the same time, the sub-basins were uplifted by general regional up-warping, with a number of 'highs' formed at the sites of former depositional basins, e.g. the Portland-Wight High above the Portland-Wight Basin (Fig. 1; see Hamblin et al., 1992).

Until the current BGS 50k land resurvey, the Sandown and Brighstone anticlines have been mapped as monoclinal features with no faulting along the steeper limb (BGS, 1975, 1995), although brief discussion of small thrusts and reverse faults (Reid and Strahan, 1889; White, 1921) and normal faulting (BGS, 1976) are found in the literature. Earlier studies of this important zone of folding have tended to emphasise the role of the reversal of movement on the underlying Permian to Mesozoic extensional down-to-the-south normal faults during Tertiary (Alpine) compression, which produced a northerly-verging and generally unfaulted monoclinal folding in the overlying late Cretaceous to early Cenozoic strata (e.g. Whittaker, 1985; Chadwick, 1993; Underhill and Patterson, 1998; Gale et al., 1999). The studies did not fully depict the development or the presence of a major reverse fault zone on the steep to overturned northern limb of the two anticlines forming the overall Isle of Wight monoclinal structure (Fig. 3a-c). Subsequently, reverse faulting along at least parts of the northern limb of the fold was recognised (Chadwick and Evans, 2005) and is now known from the BGS resurveying to come to crop within Palaeogene sequences in the area to the north of the Chalk crop.

The Sandown Anticline

The Sandown Anticline commences offshore to the southeast of Culver Cliffs, its axis crossing the coastline at Sandown Fort and running WNW towards Newchurch and although still discernable at Totland Bay, is all but lost around Calbourne (Fig. 2). The southern limb displays only gentle southerly dips. The axial region of the fold shows at first the gradual downturn of strata to the north, but the northern limb is recognised by near-vertical to overturned Chalk and Cenozoic strata, particularly in the region of Brading, just inland from Culver Cliff. Previous mapping indicated that just to the northwest of Brading around Ashey, Cenozoic strata show considerable thinning: the width of their outcrop is less than their true thickness (White, 1921). There is also evidence of bedding-parallel thrusting within the Chalk south of East Ashey, with “smashed and cleaved chalk such that bedding is barely distinguishable” (White, 1921).

The Brighstone Anticline

The Brighstone Anticline has a curvilinear axis that can be traced eastwards from just offshore to the Needles and Freshwater Bay from where it skirts the southwestern coast of the Island and appearing onshore to around Chale and Kingston. The northern limb is steeply dipping to the north with dips increasing from the Lower Greensand outcrop to the Chalk at the southern end of Chillerton Down. The Brighstone Anticline increases in amplitude westwards as the Sandown Anticline weakens to the north of it, to around Freshwater where the dip to the north reaches 80° to 90° in the Chalk. Some overturning of the Chalk around Freshwater Bay was thought to be related to superficial creep (White, 1921). The dip decreases rapidly northwards within the Cenozoic strata.

Data availability and calibration of the seismic reflection data

Seismic reflection data comprise a number of surveys of varying vintage crossing the Isle of Wight Monocline. The earliest data were acquired by BP in 1973 and still to this day represent some of the few data available north-south in the central area of the island and tying the Arreton 1 and 2 hydrocarbon exploration wells. Subsequent seismic reflection data were acquired in 1979 and 1986 (Gas Council) and 1992/1993 (Brabant Petroleum), mainly over the area of the Brighstone Anticline and northwards), but to a lesser degree across the Sandown Anticline. These data are of generally good quality, forming an open grid. A number of east west lines are available to the north, south and between the two folds. These are of more variable quality, being subparallel to the main faulting direction and thus affected by ‘noise’ from offline sources/structures (‘sideswipe’). The location of data referred to in this paper is illustrated in Fig. 2 (refer also Fig. 7).

The seismic reflection data are calibrated by a number of deep hydrocarbon exploration wells to both the north and south of the Monocline (Fig. 2). The first exploration borehole was Arreton 1, drilled in 1954, however the next was 1974 (Arreton 2) with the majority drilled between 1982 (Sandhills 1) and 1995 (Chessell 1). Subsequently, the Bouldner Copse 1 and Sandhills 2and 2z exploration wells were drilled by Northern Petroleum in 2005. The detailed calibration of two seismic reflection lines is here illustrated by the synthetic seismogram ties to the Sandhills 1 (Fig. 4) and Wilmingham 1 (1984) boreholes (Fig. 5). The seismic reflection data acquired in the late 1980s to mid 1990s is of generally good quality and the borehole ties show the expansion in the stratigraphy across the two syndepositional normal faults. It is also seen that the Base Lower Greensand, Base Chalk, Top Chalk, Base Barton Clay and Top Barton Clay levels over the footwall blocks correspond to good continuity reflections that can be reliably traced southwards into the steeply dipping northern limbs of the Brighstone and Sandown anticlines. For simplicity and clarity, interpretations of other seismic lines illustrated in this paper show only the picks for the Base Permo-Triassic, Base Lower Greensand, Base Chalk, Top Chalk, Base and Top Barton Clay levels. These picks illustrate the overall structure and detail on the steep to overturned northern limbs of the anticlines and which is the main focus of this paper.

Essentially, both the seismic reflection and borehole data prove the development of major concealed down-to-the-south basin bounding syndepositional normal fault zones underlying the two anticlines that make up the composite Isle of Wight monoclinal structure: the Needles Fault beneath the Brighstone Anticline and the Sandown Fault beneath the Sandown Anticline (Figs. 4 and 5; Chadwick and Evans, 2005). The borehole data alone illustrate the vastly differing thicknesses and disposition of pre Lower Greensand strata. To the north of the Monocline, over the footwall blocks, there is an area of elevated basement and thinner Mesozoic sequences between 774 m (Sandhills 1) and 1275 m (Wilmingham 1) thick. To the south of the Monocline, the Arreton 2 Borehole proved an unbroken Wealden to Sherwood Sandstone succession at least 2225 m thick, equating to around 1268 milliseconds (ms) two-way-travel-time (twtt) in the hangingwall block (Fig. 6).

The main faults and their relationships are shown in Fig. 7. To the south of the Needles Fault (underlying the Brighstone Anticline) is a second major east-west trending down-to-the-south intrabasinal normal fault that can be traced from the SW coast across to around Shanklin on the east side of the island and presumably beyond. In the centre of the island, its throw is not as great as it is to the west, where it is as great as that of the Needles Fault just to the north.

Unlike the Needles and Sandown faults, the intrabasinal fault does not seem to have been inverted by reversal of movement.

To the north across the footwall block regions of the Needles and Sandown faults, a series of smaller tilted and eroded fault blocks are imaged. Truncation of strata is beneath the ‘late Cimmerian Unconformity’ above which lies the early Cretaceous Lower Greensand. Within the tilted fault blocks, boreholes prove a preserved thickness of Triassic and Jurassic rocks up to the Corallian/Kimmeridge Clay of between 356 m (Sandhills 1), 755 m (Cowes 1) and 813 m (Wilmingham 1). To the south across the Sandown Fault, the Arreton 2 Borehole proved at least a 2225 m thick sequence of Triassic to Wealden strata; a ~~3-6~~ three- to six-fold increase in stratigraphical thickness across the faults (Figs. 4-6). In Arreton 2, the Jurassic strata are succeeded conformably by the Wealden strata.

Dramatic increases in stratigraphical thickness across the faults are thus shown and corroborated by borehole data (Figs. 4-6) and illustrate that major normal faults underlying the two anticlines were active during successive phases of crustal extension in Permian to Mesozoic times.

Results

The following describes the structure of the main folds observed on generally north-south oriented seismic reflection lines. Detailed interpretations of the structures indicate the development and structural evolution of the two main component structures to the Monocline: the Sandown and Brighstone anticlines. In addition, the Porchfield Anticline is imaged lying above a concealed syndepositional down-to-the-north normal fault (Fig. 4). The smaller fold has not been as deeply eroded as larger inversion folds developed in the post extensional cover sequences across southern Britain. It represents a superb illustration of the mechanism by which inversion anticlines form in the post-rift cover sequences in response to reversal of movement on former normal faults (see also Chadwick and Evans, 2005).

The seismic reflection data across the northern limbs of the two anticlines indicates the mechanism of fold development and the structures developed in association with them. A sequential series of seismic lines from east to west illustrate the development and interaction of the two anticlines. Brief descriptions of the seismic data commence with examples from the eastern and central areas of the Sandown Anticline, moving progressively westwards into the overlap zone where both folds are developed. Finally the structures in the area where only the Brighstone Anticline is developed are described.

The structures interpreted affecting the Cenozoic strata occur in a narrow zone to the north of the two main anticlines. Generally, the uppermost Chalk sequences and the Cenozoic strata produce good continuity, moderate to high amplitude reflections that can be traced south towards the anticlines to a point around 1 km from the main structure. At this point reflection continuity breaks down, particularly nearer surface. With depth, reflections are visible beneath this point and to the south. The position maps out consistently along the length of both anticlines and the change probably relates to in part a steepening of the dips but also a structural boundary that is likely to be the northern limit of reverse faulting at shallow depths that will be described below associated with the formation of the anticlines.

The deep structure of the Sandown Anticline

Seismic reflection data confirm that the Sandown Anticline results from reversal of movement on an underlying major down-to-the-south syndepositional normal fault (Figs. 2, 4, 6, 8 and 9). However, it is apparent that the northern limb of the anticline is structurally more complex than simply the continuous succession of steep to overturned beds depicted in previous interpretations of the deep structure (e.g. Chadwick, 1986, 1993; Underhill and Patterson, 1998). As will be illustrated in the series of north-south seismic lines, the pick for the top Chalk reflection is traced southwards in the subsurface to at least the position vertically below the point at which the top Chalk is at crop, where it is steeply dipping to vertical (Figs 4, 6, 8&9). In fact, the top Chalk reflection in the footwall block is generally traced further south than this point in the subsurface. It may show a curvature upwards but is still at significant depths. This indicates that the northern limb of the anticline is cut by a high-angle reverse fault that carries the top Chalk to near surface. This fault comes to crop to the north of the top Chalk crop line, within the drift covered Cenozoic strata. Smaller reverse faults are also apparent propagating northwards from the main reverse fault into and displacing the Chalk and Cenozoic sequences. The reverse fault is therefore likely to be a complex zone of faulting which on the seismic data and at crop may only ever be resolved as a fault zone. There is also evidence of possible high-angle back thrusting within the hinge and core regions of the anticline (e.g. Fig. 4).

To the east of Arreton, the main fault zone has an apparent reverse displacement of circa 510 m at top Chalk level. This increases to a possible 565 m in the central parts of the anticline crop, before diminishing to an estimated 480 m to the northwest of Arreton (Fig. 6). In the central and western parts of the anticline crop, picks for the Barton Clay indicate that a number of smaller reverse faults appear to have propagated northwards from the main reverse fault zone. These mainly affect the shallower Cenozoic strata, but the top Chalk also appears to be cut by reverse faulting. Strata are successively uplifted and brought to crop in a series of fault terraces, within which the strata often appear relatively flat-lying.

The next seismic line to the west is that tying the Sandhills 1 Borehole (Fig. 4). The main reverse fault and the smaller reverse faulting of the Cenozoic sequences to the north, offsetting the picks for the top and base Barton Clay are clearly imaged. Reverse displacement here is estimated at circa 500 m. A high-angle fault, interpreted to be a transfer fault affecting sequences in the hangingwall block, can be traced southwestwards on to the next line (Fig. 9a).

Western limits and western extension of the Sandown Anticline and the appearance of the Brighstone Anticline

In the western regions of the Sandown Anticline around Calbourne, the strike curves southwards, with an associated marked reduction in dips, to as little as 17° to the north or northwest in the Upper Chalk. This produces a marked increase in outcrop width and the area was referred to as a ‘sort of tectonic no-man’s land’ by White (1921).

A series of seismic lines to the west of that presented in Fig. 8 illustrate the deep structure of this region and the interaction of the Sandown and Needles faults (Fig. 9). This region reveals the development of a relay ramp structure between the two major faults, as previously described by Underhill and Patterson (1998) and Chadwick and Evans (2005). The ramp transferred the original normal throws on the two faults and during inversion was also responsible for partitioning the compressive deformation and the development of the reverse fault above the normal fault. Movement on one (the Sandown Fault) diminishes as re-activation and reverse movement increases on the more southerly Needles Fault. This is reflected in a complementary diminishing of the Sandown Anticline and the appearance and strengthening of the Brighstone Anticline, which is accompanied by an increase in reverse displacement and faulting of its northern limb. As the original normal movement on the Needles Fault increased westwards, so the relay ramp facilitated a decrease in displacement on the Sandown Fault.

The first sequence of three seismic lines (Fig. 9) illustrate the westwards extension of the main basin bounding Sandown Fault (refer Fig. 7) that shows a decreasing degree of reactivation and with it a diminishing in the magnitude of the reverse fault and the Sandown Anticline (Fig 9a and b). It reaches a point where the reverse faulting becomes minimal (Fig. 9c), such that the next line circa 1 km to the west reveals no reactivation and no reverse fault in the post-rift sequences (Fig. 10a). At this point, the inversion of the Needles Fault with the development of a reverse fault on the northern limb of the Brighstone Anticline (formerly the Brixton Anticline of White, 1921) is observed: reverse displacement on the Needles Fault at crop being estimated at circa 130 m. One seismic line reveals evidence for complex faulting associated with the inversion of the Sandown Fault, with what appears to be a pop-up structure developed as indicated by an apparent thrust out sequence of steeply dipping higher Chalk and Cenozoic strata (Fig. 9b).

The next two seismic lines illustrate the continued fading presence and dying out of the Sandown Anticline (Fig. 10). This is expressed simply as the mild warping and tilting of the Cretaceous and Cenozoic strata as the main deformation and displacement is transferred to the Needles Fault and the growth of the Brighstone Anticline. There is no reverse fault developed in the post-rift strata above the western extension of the relay ramp area and the bounding Sandown Fault: the reverse fault tip of the Sandown Fault is thus located between the line in Fig. 9c and that in Fig. 10a, as indicated in Fig. 7.

Again, smaller reverse faults affecting the top Chalk and Cenozoic strata as seen in the picks for the top and base Barton Clay appear to be developed to the north of the main reversed Needles Fault.

The deep structure of the Brighstone Anticline to the west

The continued growth of the Brighstone Anticline westwards, linked to the development of a major reverse fault with increasing displacement is shown in two final seismic lines, the most westerly of which ties the Wilmingham 1 Borehole (Figs 5 and 11b). Again, the Top Chalk pick can be carried southwards at depth across the footwall block to a point at least vertically beneath and seemingly south of the point at which it is at crop. There is some upturning of the Top Chalk in the footwall block into the reverse fault. Reverse displacement on the fault is estimated to increase from circa 270 m to 390 m between the two lines (Fig. 11). Reverse displacement at Top Chalk level to the south of the Wilmingham 1 Borehole is estimated to be circa 370 m (Fig. 5).

Again, seismic picks for the top and base of the Barton Clay on these lines also show evidence for the development of smaller down-to-the-north reverse faults propagating from the main reverse fault zone. The strata are upthrown in a series of fault terraces, within which the strata are relatively flat-lying in the ground immediately to the north of the Top Chalk crop and reverse fault (Figs 4, 10 and 11). The complex development of smaller reverse faulting ahead of the main reverse fault is illustrated in Fig. 11b.

The Bouldner Syncline and Porchfield Anticline

The broad Bouldner Syncline runs to the north of the Brighstone and Sandown anticlines and underlies much of the northern half of the Island (Figs 2 and 7). The axis runs from near Bembridge Harbour in the east, through Ashey, Newport, the southern part of Parkhurst Forest, Shalfleet and out to Bouldner Cliff on the west of the Island. The axis is curved and continues offshore being traced WNW for up to 32 km (20 miles) on the Hampshire mainland.

In the west, to the north of Hamstead and Newtown, the Porchfield Anticline disrupts the Bouldnor syncline. This fold is traced for nearly 3 km, trending ESE but is lost in the region of Parkhurst Forest. The Porchfield fold correlates with the low anticline of Walhampton and Durn’s Town, near Lymington on the mainland to the west.

Seismic lines reveal the underlying structure to the Porchfield Anticline (Fig. 4; Chadwick and Evans, 2005). It is a southwards verging anticline underlain by a down-to-the-north extensional fault that suffered inversion during the Cenozoic. Inversion was to a lesser degree than seen associated with the main Isle of Wight Monocline, but the seismic data illustrates very well the mechanism of fold formation during inversion and prior to the development of a reverse fault on the steeper limb.

Discussion

As outlined, the general evolution of the east-west trending fold structures within the Wessex-Channel Basin have been recognised and described since the mid to late 1980s: they overlie former basin bounding normal faults that suffered reversal of movement during Cenozoic (Alpine) compressional events that affected much of northwest Europe (e.g. Stoneley, 1982, Whittaker, 1985; Chadwick, 1986, 1993; Lake and Karner, 1987; Underhill and Patterson, 1998). The inversion structures have long been thought of as Mid-Tertiary (Miocene) in age but this was questioned by the existence of erosion of the Bembridge Limestone (Daley and Edwards, ~~(~~1971) and there is increasing evidence of a more complex history of uplift from Palaeogene times into the Quaternary (Gale et al., 1999; Newell and Evans, this volume). Inversion and some folding may even have commenced in Late Cretaceous times (Mortimore, 1986; Mortimore and Pomerol, 1991, 1997), although this is questioned by Gale et al. (1999).

Reversal of movement on the major normal faults produced narrow curvilinear zones of often intense folding of the syn- and overlying post-rift sequences producing a series of monoclines and steep-sided periclinal structures. The steeper, generally north-facing limbs of the monoclines are characterized by considerable stretching and thinning. In the more intense examples of inversion structures, of which the Chaldon Herring and Poxwell anticlines are examples, the northern limbs are cut by reverse faults (Mottram and House, 1956; House, 1961; Stoneley 1982; Chadwick, 1993). Conjugate sets of extensional mesofractures in the steep (locally overturned) limbs of the Portland-Wight monocline structures are interpreted as accommodation products related to the stretching which occurred as the monocline developed initially by drape over major, deep-seated reverse faults (Bevan, 1985; Chadwick, 1993).

It has long been known that across much of the island, the width of outcrop of the Cenozoic strata is in places less than their true thickness which is known from coastal sections and various hydrocarbon exploration boreholes drilled across the footwall block and adjacent to the monocline. Previously, the northern limb of the Monocline was seen as controlling the outcrop of what have often been viewed as a largely continuous sequence of steeply dipping to overturned Cretaceous and Cenozoic strata on the northern limbs of the Sandown and Brighstone anticlines (e.g. BGS, 1975, 1995; Gale et al., 1999). Seismic interpretations (e.g. Chadwick, 1986, 1993; Underhill and Patterson, 1998) had tended to, perhaps unwittingly, re-inforce such a picture (Fig. 3), although Chadwick (1993) did state that due to steep dips, the internal details of the large inversion structure cannot be resolved on seismic reflection data.

Steepening of the northern limbs to the Sandown and Brighstone anticlines on the Isle of Wight now appears to have been accompanied by reverse faulting, as first described by Chadwick and Evans (2005). Since the interpretations of Chadwick (1986, 1993) and Underhill and Patterson (1998), more recently acquired seismic reflection data with improved processing providing increased resolution have become available. These data led to the initial interpretations of a reverse fault on the northern limb of the Sandown Anticline in Chadwick and Evans (2005). Subsequent detailed work using these improved seismic data during the remapping of the Isle of Wight sheet has enabled a greater degree of interpretation in the zone of steeper dips. Through an iterative process of discussion and testing by detailed intensive field mapping work, it has provided further insights into some of the main structures and smaller ones affecting the late Cretaceous and Cenozoic strata on the northern limbs of the Sandown and Brighstone anticlines. We have here, for the first time, described previously unrecognised major reverse fault zones that cut the mid-Cretaceous to Cenozoic strata along almost the entire lengths of the northern limbs of the Brighstone and Sandown anticlines.

The reverse fault zones come to crop just to the north of the Chalk within the steeply dipping Cenozoic strata and may have up to 560 m displacement at top Chalk levels, a figure similar to that of Gale et al. (1999) for the mid-late Eocene uplift that they postulate exposed the Chalk in the crest of the Sandown Anticline. The present-day level of erosion on the Isle of Wight Monocline is such that the evidence for mid-late Eocene erosion has been removed by later Tertiary uplift and erosion. However, we do not see a problem in the amount of Eocene uplift proposed by Gale et al. (1999), or accommodating their model into the general model of reverse faulting representing the last major control on the structure of the folds' northern limbs. Although sandbox models of inverted planar and listric detachment faults and domino faults reveal the reverse faulting in post extension strata occurs soon after inversion commences (Fig. 12; Buchanan and McClay, 1991), there is some folding of these strata in the models. Seismic sections of similar inversion folds from the southern North Sea (e.g. Badley et al., 1989) show folding of strata occurs prior to breakthrough of the reverse fault. Clearly there was folding of the Chalk and Cenozoic strata, which are near vertical at crop and some seismic lines across the folds show upturning of the top Chalk reflector at depth in the footwall block adjacent to the fold (although velocity effects may be in part responsible for this). It is likely, therefore, that the Chalk and Cenozoic strata suffered folding, perhaps local overturning and extensional thinning (e.g. Bevan, 1985; Chadwick, 1993), prior to the reverse fault breaking through to produce the 550 m reverse movement at top Chalk levels. Overall Cenozoic uplift will, therefore, be greater than the 500 m+ mid-late Eocene uplift proposed by Gale et al. (1999), being the sum of the fold amplitude and reverse displacement described here, perhaps 1 km. This is likely to be a maximum figure because the fold amplitude recognised today will also probably represent an increase due to growth of the fold during the reverse faulting, as a result of on-going compression and tightening of the structure.

The likely presence of a major reverse fault on the steepened northern limbs of inversion folds across the Weald and Wessex basins was noted from some of the earliest accounts (e.g. Reid and Strahan, 1889). They describe the sudden 'downward plunge' of the beds on the north side of all the anticlines and how this seemed to be the pre-cursor to the formation of a thrust-plane or slide-fault seen on the mainland. Although they found no evidence of a similar thrust-plane at either end of the Isle of Wight, they described at Ashey how the middle part of the Bracklesham Series to the basement bed of the London Clay is absent, i.e. that the Bagshot Sands and most of the London Clay are missing. White (1921) described it thus: "….round the blunt northward salient of the Downs about Ashey the upturned beds of Eocene and Oligocene age are so compressed that the width of outcrop, in places, is less than their true thickness" and "…close by West Ashey, the cutting north of the tunnel under the road formerly showed a remarkable section, in which the lower beds of the London Clay are succeeded by clays of Bracklesham age." The use of 'succeeded' in this context being not in a conformable stratigraphical sense, but describing a lateral traverse through near-vertical beds, hence suggesting the absence of strata. Reid and Strahan (1889) argued the relationship hereabouts: "….shows that a strike fault of a peculiar character must there be present. The bedding on each side of the presumed line of fault is perfectly vertical and to account for the absence of about 400 feet of clays and sands the simplest explanation seems to be that adopted in the new edition of Sheet 47 of the Horizontal Sections now in preparation - that at Ashey a thrust-fault occurs, and that its form and effect on the beds correspond closely with what we know is found on the mainland."

A cross section on the 1976 version of the 1:50k map (BGS, 1976) through West Ashey depicts a thinning of the near-vertical Cenozoic strata with a high-angle down-to-the-north normal fault developed within the steeply dipping early Cenozoic strata on the northern limb of the Sandown Anticline, juxtaposing the Bagshot Beds against the Reading Beds and London Clay to the south (Fig. 3c). The stratal relationships can also be interpreted as southward-dipping high-angle reverse faulting of the steep and thrust out northern limbs of the Sandown and Brighstone anticlines.

The smaller scale reverse faults interpreted to the north of the main reverse fault zone are interesting and are interpreted as shortcut faults seen to develop in sandbox models of inverted planar and listric detachment faults and domino faults (e.g. Buchanan and McClay, 1991): refer the circled areas of the two fault type inversion models in Fig. 12. It is recognised that important limitations exist in scaled analogue models and that these must be borne in mind when interpreting and applying the results. Of note is that faults are formed by granular shear processes and not by grain breakage, which means that the processes do not replicate fault mechanics in nature (Scholz, 1990). Also, in the models fault propagation growth anticlines characteristic of many natural inversion structures are only poorly developed. This is related to the homogenous nature of the sand pack and the lack of strong competent bedding units that could undergo folding during inversion (McClay, 1995). When modelling materials such as apparently more competent clay, inversion leads to more of a fault propagation growth anticline (Mitra, 1993; McClay 1995).

During inversion, a reverse fault propagates into the overlying post-extension and syn-inversion 'strata', producing steepened and overturned strata prior to a reverse fault propagating and cutting the steepened limb (Fig. 12). A very characteristic feature of all experimental models is the development of short-cut thrusts with small fault propagation folds at their tips in the footwall to the reactivated extensional faults. At high values of contraction, lower angle thrusts develop and may incorporate basement slices within the inversion structure (McClay, 1995).

As seen by the interpretation of seismic reflection data presented here, reflections originating from the Cenozoic strata, in particular the top and base of the Barton Clay, indicate that smaller high-angle reverse faults have propagated northwards within the post extensional strata in the footwall block from the main fault zone. They produce a series of upthrown fault terraces. Strata may be drawn up vertically and have suffered tectonic thinning adjacent to these smaller reverse faults and perhaps more so adjacent to the main fault. These structures bear striking resemblance to smaller ‘short-cut’ faults produced in footwall block sequences during sand box experiments of extensional faults that are subsequently inverted (Buchanan and McClay, 1991; McClay, 1995, 1996; Yamada and McClay, 2004) and also mapped affecting inverted Cretaceous basinal sequences in the Pyrenees (Garcia-and Muñoz, 2000). These structures are concealed beneath the drift covered ground, or talus, to the north of the Chalk and it is unlikely that augering of alternating sandy and clayey strata in this area could ever accurately delineate and map the structures in detail.

More generally, the post-extension strata in Fig. 12 are broadly representative of the steeply dipping Upper Cretaceous (mainly Chalk) to Eocene succession on the Isle of Wight (the heavier weighted line is the inferred Chalk-Cenozoic boundary). It can be seen that the strata are initially folded into a footwall-verging monocline and even overturned. Continued reversal of the extensional fault leads to a thrust developing which cuts through the steepened fold limb, juxtaposing steep to overturned lower post-extension (Cenozoic) strata against younger post-extension (Cenozoic) strata and eventually, syn-extension (Jurassic-Lower Cretaceous) strata against post-extension (Cenozoic) strata. The same stratal geometries and juxtapositions have been described from the seismic reflection data here.

Recent and previous mapping provides important detail of small-scale compressional structures within the Chalk at crop. At present, not all these have been incorporated into the general high-angle reverse fault model. However, seismic reflection data suggest the presence of small-scale reverse faulting within the Chalk on the northern limb and within the core of the anticlines. An example of this is seen in a disused Chalk pit near Nunwell House (Fig. 2; 459225, 087205). The Portsdown Chalk, steeply dipping to the north, is cut by a high-angle reverse fault that clearly truncates flint seams in the host chalk (Fig. 8; P Hopson, pers comm. 2010). The sub-seismic resolution fault dips to the south, throws down to the north and strikes roughly east-west. The fault surface is slickensided and a crush zone 0.5 to 1 m wide is developed immediately above the fault in the Chalk of the upthrown (southern) hangingwall block. It clearly results from failure of the steepened fold limb, in much the same way as the larger fault above which it is developed.

The smaller-scale structures at crop should further refine understanding of the structure and the detailed structural evolution of the Monocline. To illustrate this, at Nunwell Rookery the dip of the Chalk is between 80° and 90° and it is “much slickensided, with many of the flints crushed to powder; phenomena not uncommon on the northern side of the Central Downs” (White, 1921). The same author also described how at the Ryde Waterworks quarry south of East Ashey, that “the Chalk is traversed by a thrust-fault which nearly coincides with the bedding.” At West Ashey quarry, the chalk is similarly described as smashed and cleaved with two nearly vertical strike-faults, accompanied by breccias, seen in the eastern face of the working. In the southern face there are indications of a horizontal shift along a vertical dip-fault. Some could, for instance, have origins similar to that of the Ballard Down Fault described affecting the Purbeck Monocline to the west (Underhill and Patterson, 1998) and Reidand Strahan (1889) describe small-scale, southward-directed reverse faulting of the flat-lying Cenozoic strata between How Ledge and Colwell Chine to the north of the Brighstone Anticline on the coast west of Freshwater.

Conclusions

Although a degree of uncertainty exists in the imaging of the succession in the region of the steeply dipping strata on the northern limbs of the two constituent folds to the composite Isle of Wight Monocline structure, major reverse faulting is interpreted in these regions. Such structures are not currently recognised in the current interpretations of cliff sections at Whitecliff and Alum Bay at either end of the island (as shown for example in Insole et al., 1998). This may be seen as a potential weakness in the interpretations proposed here. We would agree (and have alluded to this above) that in the region of steeply dipping beds, imaging of the sequences will be impossible and so a degree of uncertainty exists regarding the actual locations of, and displacements on, the reverse faults. However, we would suggest that a number of lines of evidence support the reverse faulting and perhaps question the interpretation of the coast sections. These include the known thicknesses of Tertiary strata proved in nearby boreholes and the lack of space on the ground to the north of the steeply dipping Chalk of the northern limbs to accommodate such thicknesses of strata. Added to this is the rapid lateral change from vertical to horizontal strata seen inland and supported by the absence of parts of the succession (for example within the Ashey cutting mentioned in the memoir; and the termination of the Bembridge Limestone only a short distance inland of Whitecliff Bay demonstrated during surveying), which add credence the interpretation proposed in this paper. The authors point out (although not attempting to demonstrate faulting) that there are significant parts of the succession obscured at Alum Bay (in the valley that carries the cable car and founded on the Barton Group) and in Whitecliff Bay (within the Barton Clay/Becton Sand section immediately south of the Bembridge Limestone). Are these potential sites where 'within-bed' faulting may occur? The squeezing of beds necessary to accommodate the rapid attitude change of the beds as demonstrated in both published coastal sections could equally be achieved by faulting within alternating lithologies that are very similar in nature.

Acknowledgements

We are grateful to members of the Isle of Wight mapping team, particularly P Hopson and Drs A Farrant and A Newell for many helpful and lively discussions on the structure and evolution of the Isle of Wight monocline and in particular the possible presence and location of a reverse fault at crop. Thanks are also extended to BGS colleagues, especially Drs S Holloway, A Newell and D Ritchie, all of whose reviews improved earlier drafts of the manuscript. The review provided by Prof A Gale is also acknowledged, particularly regarding the apparent absence of faulting at the cliff sections. Thanks are also extended to Neil Anderton and UKOGL for permissions to use the seismic lines in this paper (website: http://www.ukogl.org.uk/). The paper is published with the permission of the Executive Director of the British Geological Survey (NERC).

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Figure Captions

Fig.1. Location map and principal structural elements of the Wessex Basin (modified from Chadwick Evans, 2005). Mesozoic extensional structural elements in black, Cenozoic compressional features in red. The Pewsey, Wardour-Portsdown and Abbotsbury-Ridgeway-Purbeck-Wight structures form three distinct and major lines of Cenozoic (Tertiary) inversion structures.

Fig.2. Location map showing the general structures and place names and seismic line locations (thin grey solid lines) referred to and described in the text.

Fig.3. North-south line drawings of previous interpretations of the deeper structure Isle of Wight Monocline, in particular the steep to overturned northern limb. (a) based upon seismic interpretation, showing no faulting (Underhill Patterson, 1998), (b) based upon seismic interpretation showing no faulting (Chadwick, 1986, 1993), (c) simple fold with no faulting (Gale et al. 1999), (d) line of section from previous published 1:50k map showing steep down-to-the-north normal fault affecting the Cenozoic strata on the northern limb (BGS, 1976).

Fig.4. Calibration and interpretation of seismic reflection line tying the Sandhills 1 Borehole (refer Fig. 7 for line location). Interpretation is of a large reverse fault cutting the northern limb of the Sandown Anticline and arising from reversal of movement on an underlying major syndepositional normal fault. The reverse fault propagated upwards from the normal fault in the overlying post-rift strata during inversion. Possible minor reverse faulting propagating to the north from the main fault is also indicated.

Fig.5. Calibration and interpretation of seismic reflection line tying the Wilmingham 1 Borehole (refer Fig. 7 for line location). Interpretation is of a large reverse fault cutting the northern limb of the Brighstone Anticline and arising from reversal of movement on an underlying major syndepositional normal fault. The reverse fault propagated upwards from the normal fault in the overlying post-rift strata during inversion. Possible minor reverse faulting propagating to the north from the main fault is also indicated.

Fig.6. Two north-south seismic lines across the Sandown Anticline to the north and northwest of Arreton (refer Fig. 7 for line locations) illustrating the high-angle reverse fault affecting the northern limb of the anticline. Displacement at top Chalk levels in the east (a) is estimated at c. 565m diminishing to c. 430 on the more westerly line (b). Again, smaller reverse faulting affecting the Chalk and Cenozoic strata is also thought to exist to the north of the main reverse fault. Also shown is the Arreton #2 tie with base Permo-Triassic at c. 1268 ms twtt (part a).

Fig.. Map showing the location of the main basin bounding Needles and Sandown faults and the relay ramp between them. The area of inversion on the Sandown Fault is outlined passing westwards into an area where the extension of the normal fault shows no apparent inversion or development of a reverse fault. The reverse fault tip can thus be identified between two seismic lines (see Figs 9 and 10).

Fig.8. Seismic line from the eastern region of the Sandown Anticline near Brading (refer Fig. 7 for line location), illustrating the high-angle reverse fault affecting the northern limb of the anticline. Displacement at top Chalk levels is estimated at c. 500m and a smaller reverse fault affecting the Chalk and Cenozoic strata is also thought to exist to the north of the main reverse fault. Also shown are two photographs of the eastern wall of the Nunwell House Quarry in which a high-angle reverse fault affecting the Portsdown Chalk is identified (note the photograph is reversed to fit with the orientation of the seismic line, which is viewed looking west). The fault lies above the underlying major reverse fault as depicted in the line drawing sketches. BGS photographs taken by P Hopson: P749158 and P749159.

Fig.9. Series of three north-south seismic lines (refer Fig. 7 for line locations) across the western regions of the Sandown Anticline (parts a and b) and the eastern regions of the Brighstone Anticline (parts b and c). The ground between represents the relay ramp developed between the two original down-to-the-south syndepositional faults. The reversal of movement on the Sandown fault is seen to diminish together with the inversion fold and reverse fault in the overlying post-rift strata. A complementary increase in the reversal of movement on the Needles Fault and growth of the Brighstone Anticline is seen.

Fig. 10. Two north-south seismic lines across the eastern regions of the Brighstone Anticline (refer Fig. 7 for line locations), illustrating the high-angle reverse fault affecting the northern limb of the anticline. Displacement at top Chalk levels is estimated at c. 380 m on the more easterly line (a), increasing to c. 430 m on the more westerly line (b). Again, smaller reverse faulting affecting the Chalk and Cenozoic strata is also thought to exist to the north of the main reverse fault.

Fig, 11. Final western pair of pair of north-south seismic lines across the Brighstone Anticline (refer Fig. 7 for line locations), illustrating the high-angle reverse fault affecting the northern limb of the anticline. Displacement at top Chalk levels is estimated at c. 270 m on the more easterly line (a), increasing to c. 430 m on the more westerly line (b). Again, smaller reverse faulting affecting the Chalk and Cenozoic strata is also thought to exist to the north of the main reverse fault.

Fig. 12. Line drawings of sandbox models for inverted planar and listric faults (after Buchanan and McClay, 1991). Also shown are the approximate topographic level for the Isle of Wight folds in the inverted sequences and the proposed structural position at crop within the modelled structures, based upon stratal geometries and faulting interpreted on seismic reflection data and described at crop.

Figures – Evans et al

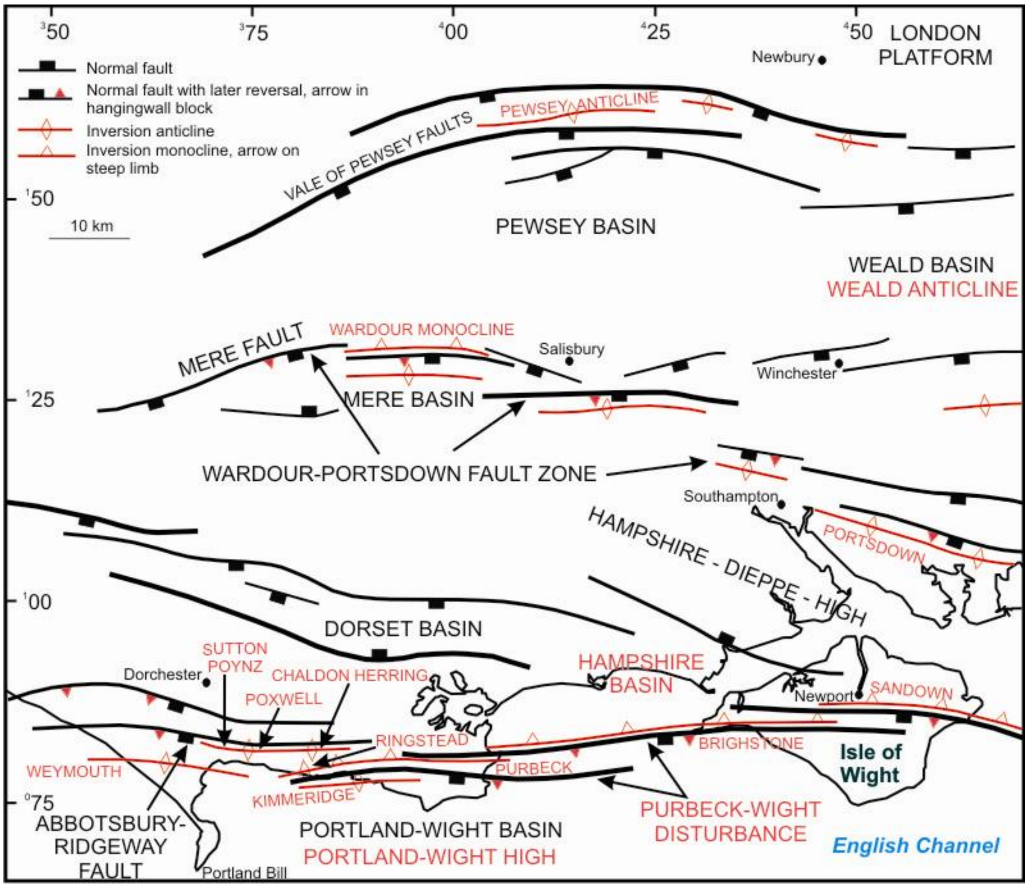
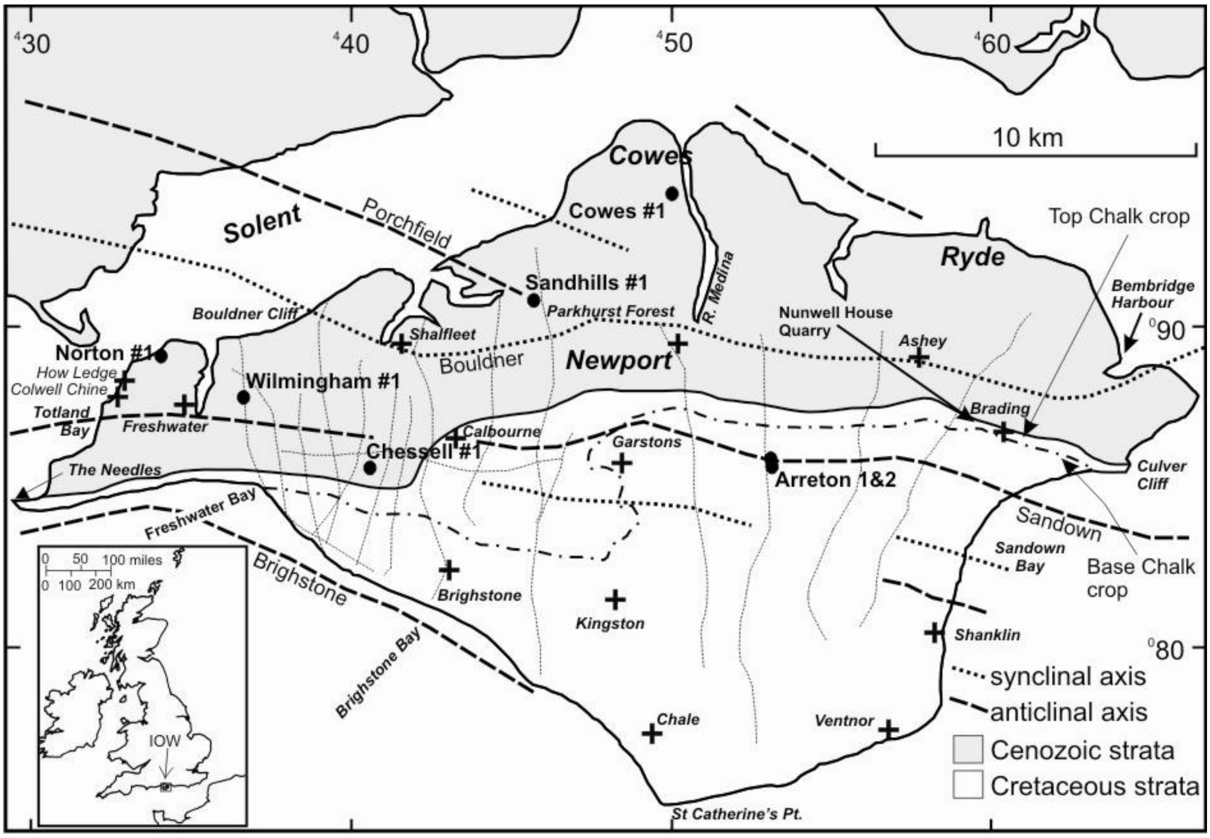


Figure 1.



430
440
450
460
10 km
Cowes
Cowes #1
Solent
Porchfield
Top Chalk crop
Ryde
Sandhills #1
Bembridge Harbour
Bouldner Cliff
Parkhurst Forest
R. Medina
Nunwell House Quarry
090
Norton #1
Shalfleet
Ashey
How Ledge
Bouldner
Newport
Colwell Chine
Wilmingham #1
Brading
Totland Bay
Freshwater
Calbourne
Garstons
Culver Cliff
Chessell #1
Arreton 1&2
The Needles
Freshwater Bay
Sandown
Sandown Bay
Base Chalk crop
Brighstone
Brighstone
Kingston
Shanklin
080
Brighstone Bay
synclinal axis
anticlinal axis
Chale
Ventnor
Cenozoic strata
Cretaceous strata
St Catherine's Pt.
0 50 100 miles
0 100 200 km
IOW

Figure 2.

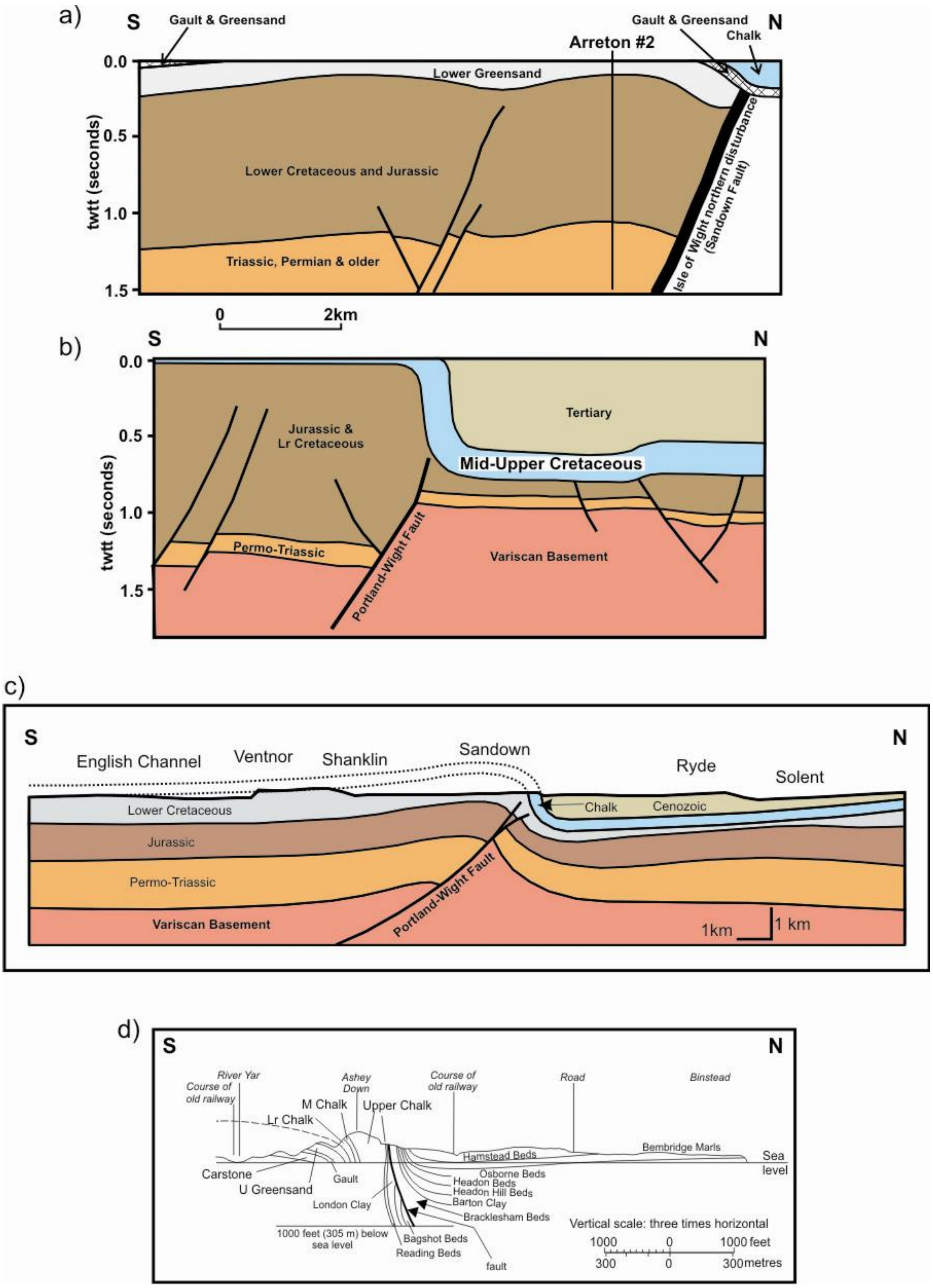

a)
S
Gault & Greensand
Gault & Greensand
N
Chalk
Arreton #2
0.0
Lower Greensand
0.5
1.0
1.5
twtt (seconds)
Lower Cretaceous and Jurassic
Triassic, Permian & older
Isle of Wight northern disturbance (Sandown Fault)
0
2km
b)
S
N
0.0
0.5
1.0
1.5
twtt (seconds)
Jurassic & Lr Cretaceous
Tertiary
Mid-Upper Cretaceous
Permo-Triassic
Portland-Wight Fault
Variscan Basement
c)
S
N
English Channel
Ventnor
Shanklin
Sandown
Ryde
Solent
Lower Cretaceous
Chalk
Cenozoic
Jurassic
Permo-Triassic
Portland-Wight Fault
Variscan Basement
1km
1 km
d)
S
N
River Yar
Course of old railway
Ashey Down
Course of old railway
Road
Binstead
M Chalk
Upper Chalk
Lr Chalk
Hamstead Beds
Bembridge Marls
Sea level
Carstone
U Greensand
Gault
London Clay
Osborne Beds
Headon Beds
Headon Hill Beds
Barton Clay
Bracklesham Beds
1000 feet (305 m) below sea level
Bagshot Beds
Reading Beds
fault
Vertical scale: three times horizontal
1000
0
1000 feet
300
0
300 metres

Figure 3.

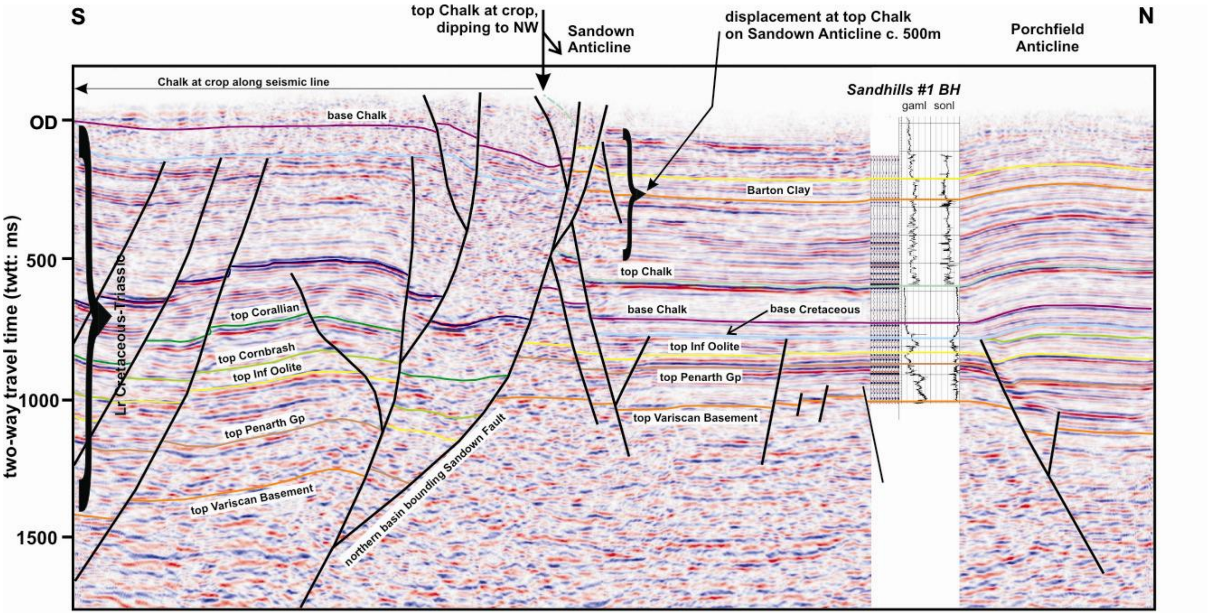


Figure 4.

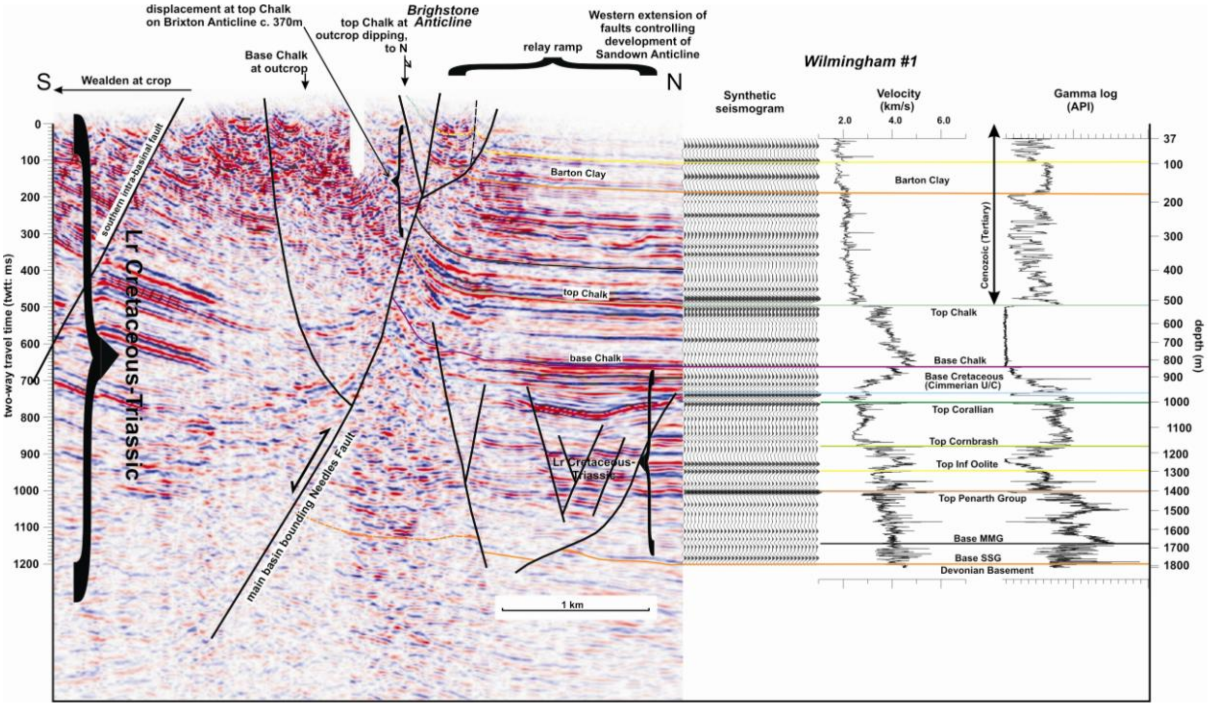


Figure 5.

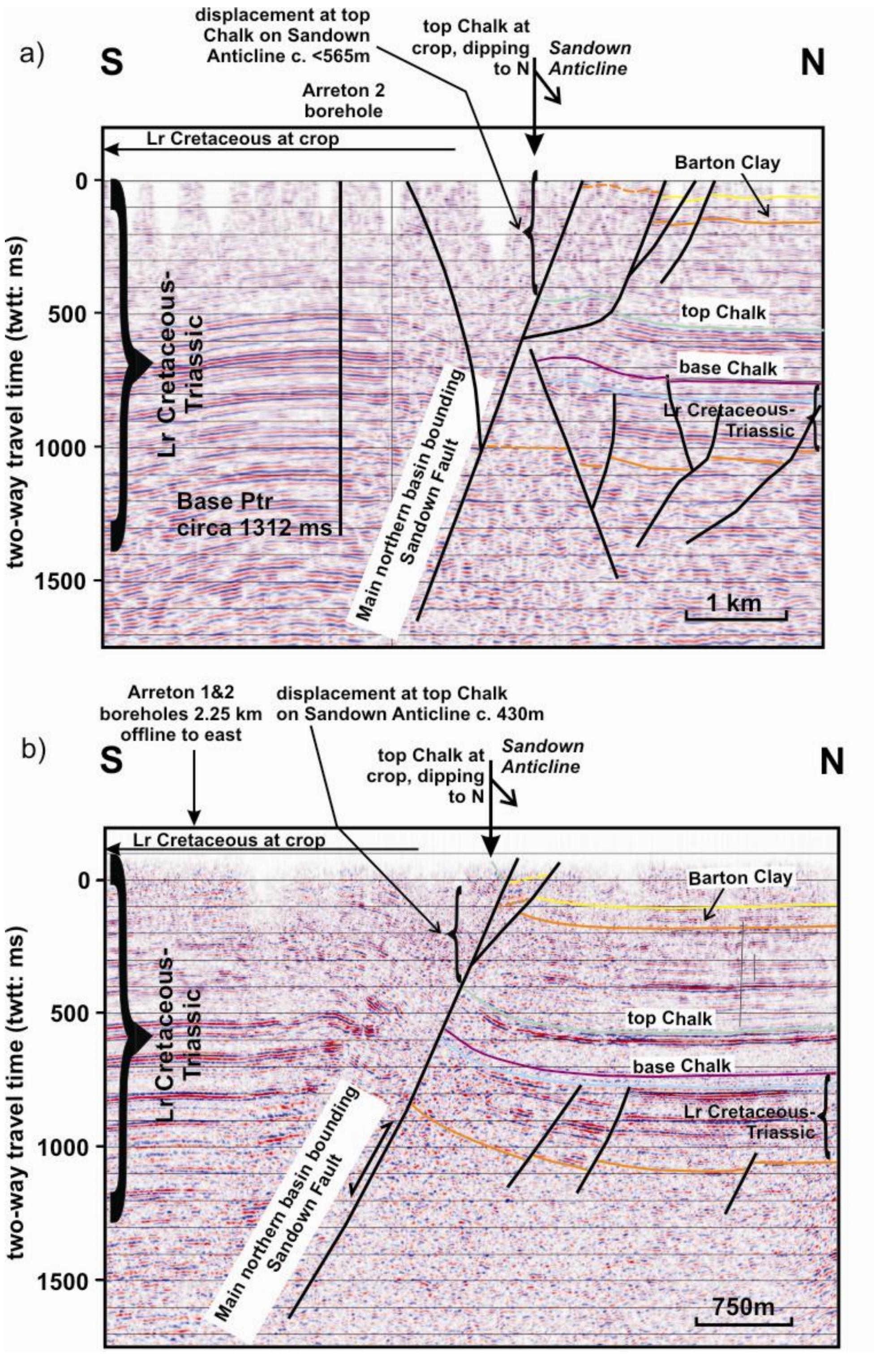
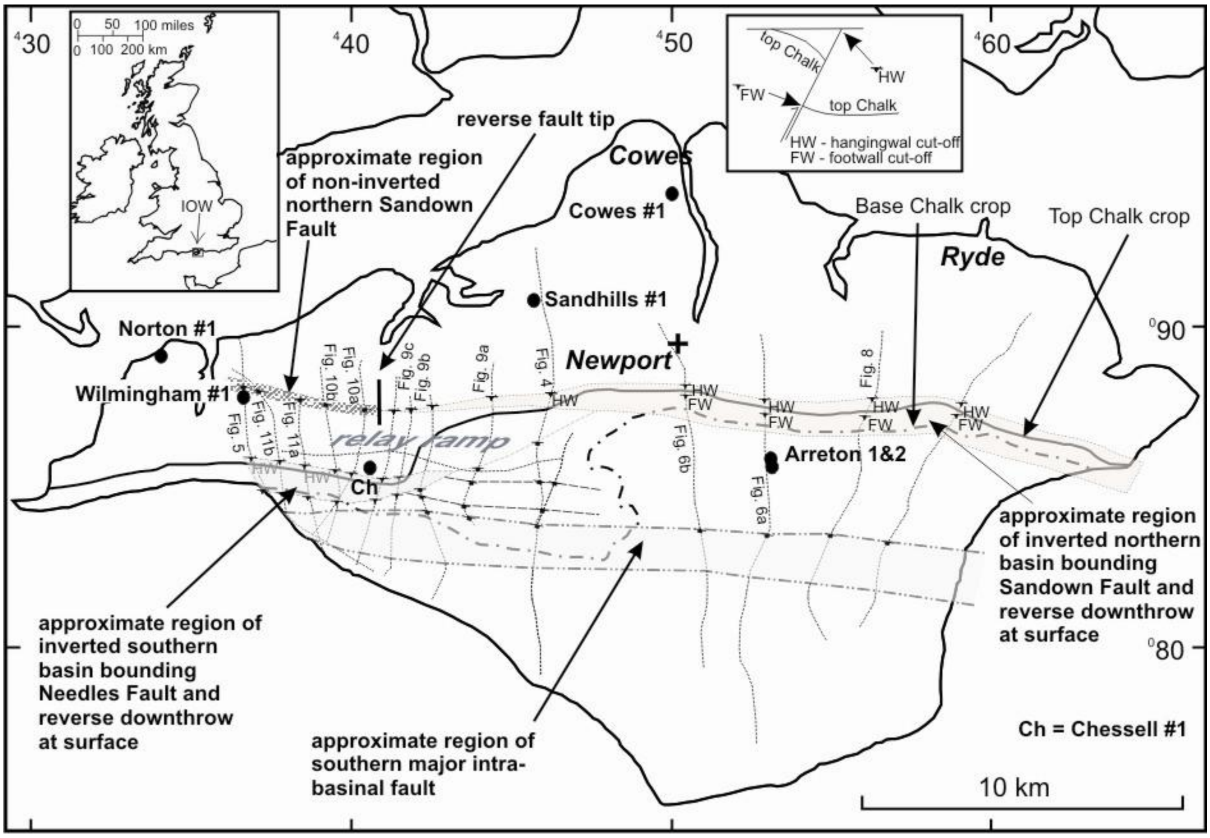

a)
S
N
displacement at top Chalk on Sandown Anticline c. <565m
top Chalk at crop, dipping to N
Sandown Anticline
Arreton 2 borehole
Lr Cretaceous at crop
Barton Clay
top Chalk
base Chalk
Lr Cretaceous-Triassic
Lr Cretaceous-Triassic
Base Ptr circa 1312 ms
Main northern basin bounding Sandown Fault
two-way travel time (twtt: ms)
0
500
1000
1500
1 km
b)
S
N
Arreton 1&2 boreholes 2.25 km offline to east
displacement at top Chalk on Sandown Anticline c. 430m
top Chalk at crop, dipping to N
Sandown Anticline
Lr Cretaceous at crop
Barton Clay
top Chalk
base Chalk
Lr Cretaceous-Triassic
Lr Cretaceous-Triassic
Main northern basin bounding Sandown Fault
two-way travel time (twtt: ms)
0
500
1000
1500
750m

Figure 6.



⁴30
⁴40
⁴50
⁴60
⁰90
⁰80
0 50 100 miles
0 100 200 km
IOW
top Chalk
top Chalk
HW
FW
HW - hangingwal cut-off
FW - footwall cut-off
reverse fault tip
approximate region of non-inverted northern Sandown Fault
Cowes
Cowes #1
Base Chalk crop
Top Chalk crop
Ryde
Sandhills #1
Norton #1
Wilmingham #1
Newport
Fig. 5
Fig. 11b
Fig. 11a
Fig. 10b
Fig. 10a
Fig. 9c
Fig. 9b
Fig. 9a
Fig. 4
Fig. 6b
Fig. 6a
Fig. 8
relay ramp
Ch
Arreton 1&2
HW
FW
approximate region of inverted northern basin bounding Sandown Fault and reverse downthrow at surface
approximate region of inverted southern basin bounding Needles Fault and reverse downthrow at surface
approximate region of southern major intra-basinal fault
Ch = Chessell #1
10 km

Figure 7.

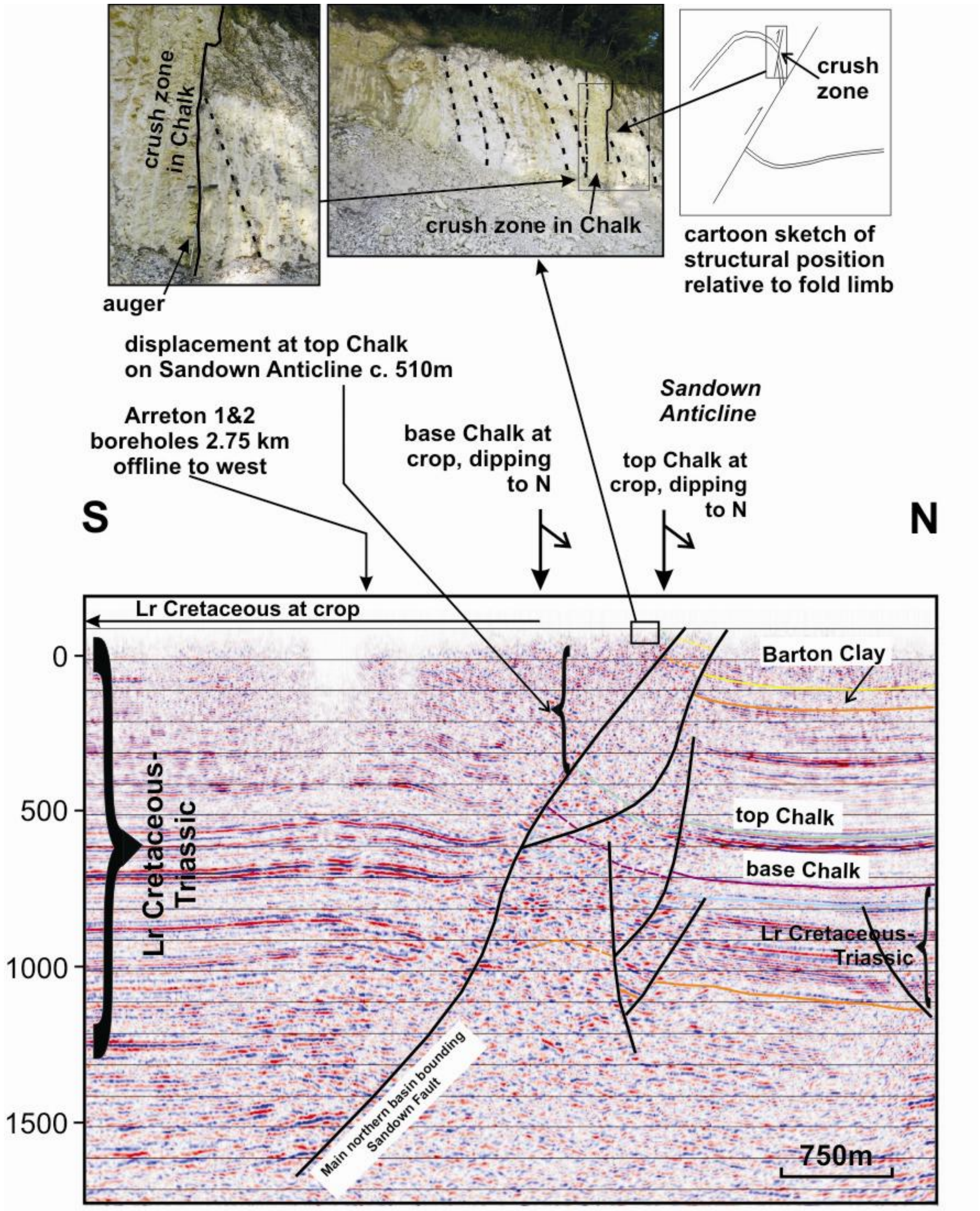

crush zone in Chalk
auger
crush zone in Chalk
crush zone
cartoon sketch of structural position relative to fold limb
displacement at top Chalk on Sandown Anticline c. 510m
Arreton 1&2 boreholes 2.75 km offline to west
base Chalk at crop, dipping to N
Sandown Anticline
top Chalk at crop, dipping to N
S
N
Lr Cretaceous at crop
0
500
1000
1500
Lr Cretaceous-Triassic
Barton Clay
top Chalk
base Chalk
Lr Cretaceous-Triassic
Main northern basin bounding Sandown Fault
750m

Figure 8.

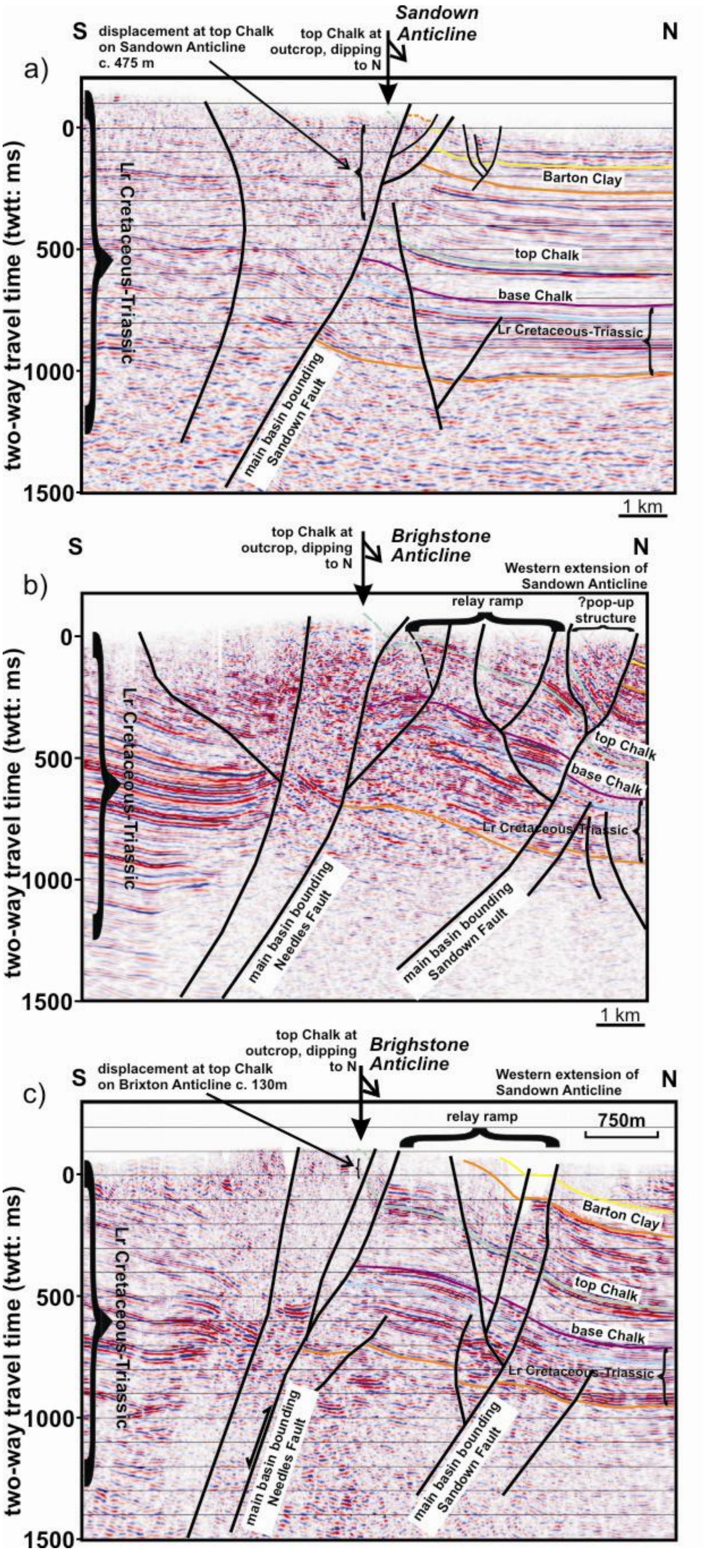

a)
S
N
displacement at top Chalk on Sandown Anticline c. 475 m
top Chalk at outcrop, dipping to N
Sandown Anticline
two-way travel time (twtt: ms)
0
500
1000
1500
Lr Cretaceous-Triassic
Barton Clay
top Chalk
base Chalk
Lr Cretaceous-Triassic
main basin bounding Sandown Fault
1 km
b)
S
N
top Chalk at outcrop, dipping to N
Brighstone Anticline
Western extension of Sandown Anticline
relay ramp
?pop-up structure
two-way travel time (twtt: ms)
0
500
1000
1500
Lr Cretaceous-Triassic
top Chalk
base Chalk
Lr Cretaceous-Triassic
main basin bounding Needles Fault
main basin bounding Sandown Fault
1 km
c)
S
N
displacement at top Chalk on Brixton Anticline c. 130m
top Chalk at outcrop, dipping to N
Brighstone Anticline
Western extension of Sandown Anticline
relay ramp
750m
two-way travel time (twtt: ms)
0
500
1000
1500
Lr Cretaceous-Triassic
Barton Clay
top Chalk
base Chalk
Lr Cretaceous-Triassic
main basin bounding Needles Fault
main basin bounding Sandown Fault

Figure 9.

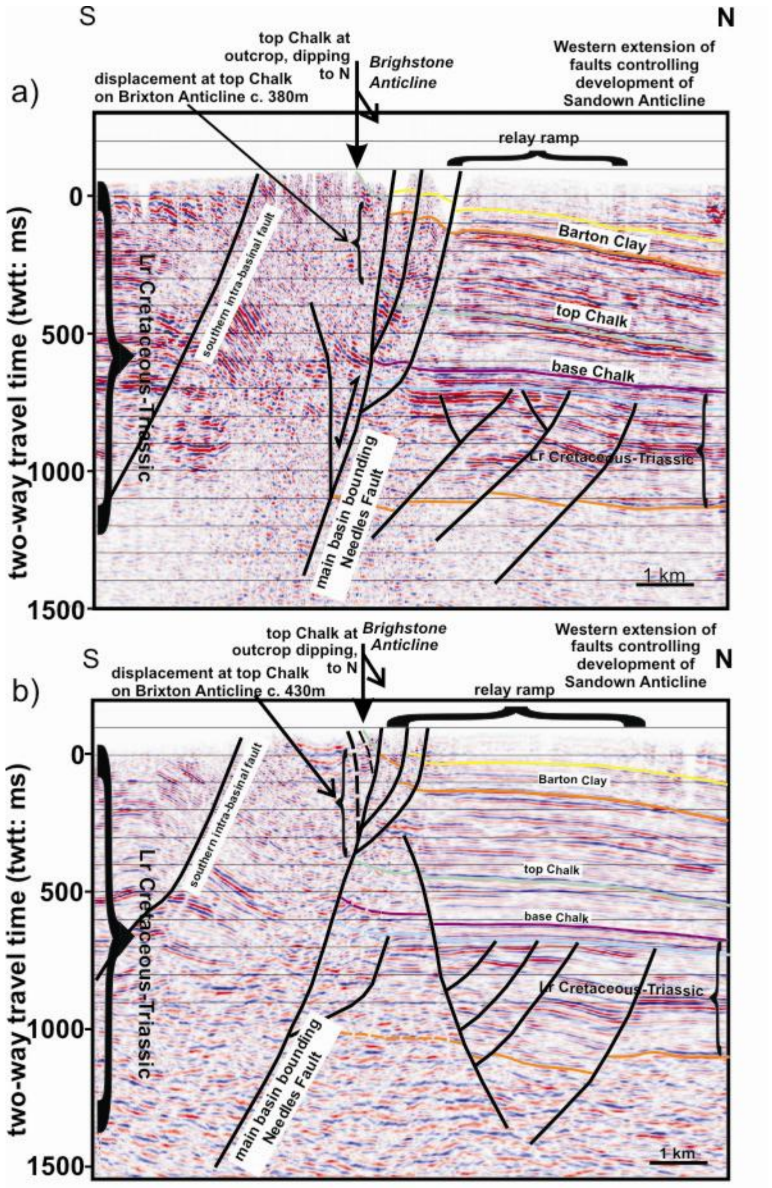

S
N
a)
top Chalk at outcrop, dipping to N
Brighstone Anticline
displacement at top Chalk on Brixton Anticline c. 380m
Western extension of faults controlling development of Sandown Anticline
relay ramp
Barton Clay
top Chalk
base Chalk
southern intra-basinal fault
Lr Cretaceous-Triassic
main basin bounding Needles Fault
Lr Cretaceous-Triassic
two-way travel time (twtt: ms)
0
500
1000
1500
1 km
b)
top Chalk at outcrop dipping, to N
Brighstone Anticline
displacement at top Chalk on Brixton Anticline c. 430m
Western extension of faults controlling development of Sandown Anticline
relay ramp
Barton Clay
top Chalk
base Chalk
southern intra-basinal fault
Lr Cretaceous-Triassic
main basin bounding Needles Fault
Lr Cretaceous-Triassic
two-way travel time (twtt: ms)
0
500
1000
1500
1 km

Figure 10.

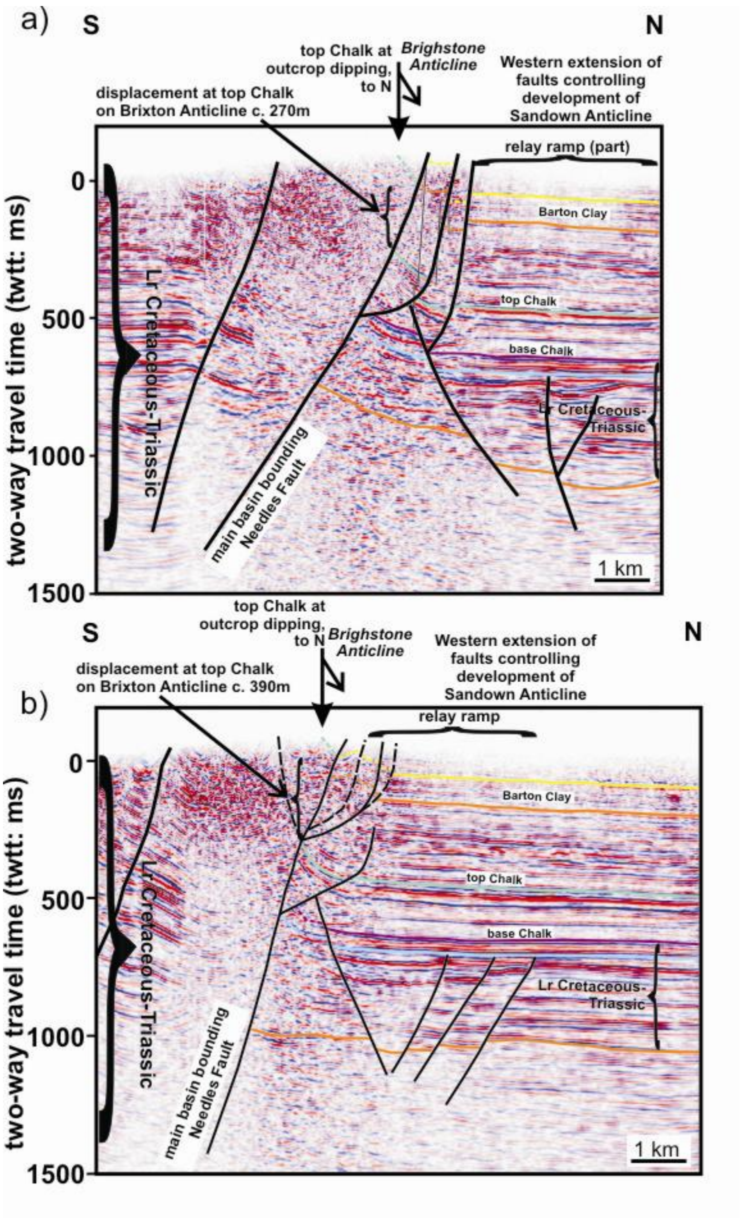

a)
S
N
top Chalk at outcrop dipping, to N
Brighstone Anticline
Western extension of faults controlling development of Sandown Anticline
displacement at top Chalk on Brixton Anticline c. 270m
relay ramp (part)
Barton Clay
top Chalk
base Chalk
Lr Cretaceous-Triassic
Lr Cretaceous-Triassic
main basin bounding Needles Fault
two-way travel time (twtt: ms)
0
500
1000
1500
1 km
b)
S
N
top Chalk at outcrop dipping, to N
Brighstone Anticline
Western extension of faults controlling development of Sandown Anticline
displacement at top Chalk on Brixton Anticline c. 390m
relay ramp
Barton Clay
top Chalk
base Chalk
Lr Cretaceous-Triassic
Lr Cretaceous-Triassic
main basin bounding Needles Fault
two-way travel time (twtt: ms)
0
500
1000
1500
1 km

Figure 11.

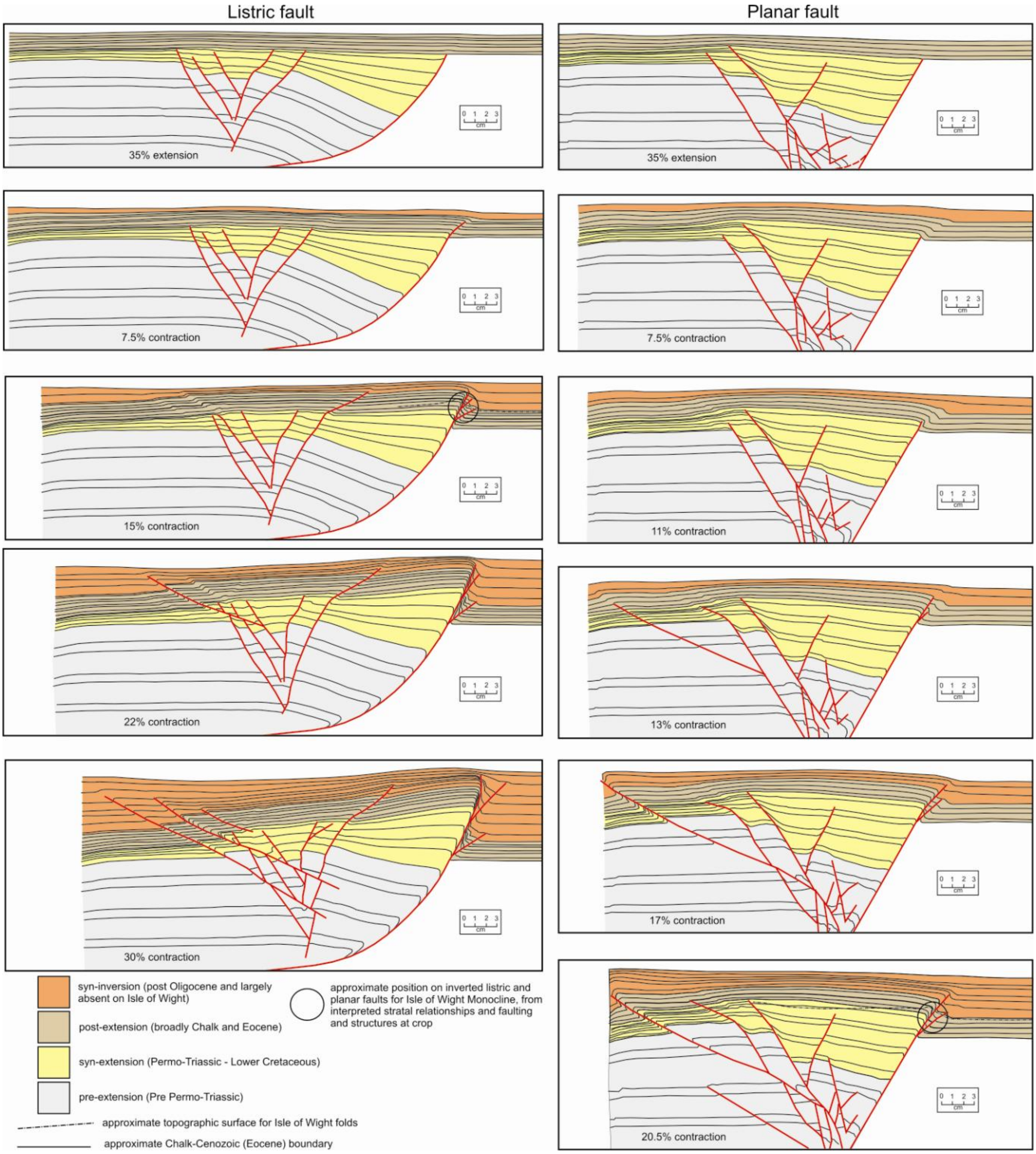

Listric fault
Planar fault
35% extension
7.5% contraction
15% contraction
22% contraction
30% contraction
35% extension
7.5% contraction
11% contraction
13% contraction
17% contraction
20.5% contraction
0 1 2 3
cm
syn-inversion (post Oligocene and largely absent on Isle of Wight)
post-extension (broadly Chalk and Eocene)
syn-extension (Permo-Triassic - Lower Cretaceous)
pre-extension (Pre Permo-Triassic)
approximate topographic surface for Isle of Wight folds
approximate Chalk-Cenozoic (Eocene) boundary
approximate position on inverted listric and planar faults for Isle of Wight Monocline, from interpreted stratal relationships and faulting and structures at crop

Figure 12.